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Indian Standard

FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT

Generic Specification

(First Reprint APRIL 1991)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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INDIAN STANDARD
FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT
Generic Specification

National Foreword

This Indian Standard, which is identical with IEC Pub 384-1/QC 300000(1982)Fixed capacitors for use in electronic component–Part 1: Generic specification,' issued by the International Electrotechnical Commission (IEC), was adopted by the Bureau of Indian Standards on 15 March 1988 on the recommendation of Capacitors Sectional Committee and approval of Electronics and Telecommunication Division Council.

Wherever the words 'International Standard' appear, referring to this standard, they should be read as 'Indian Standard'.

Cross References

In this Indian Standard, the following International Standards are referred to. Read in their respective place the following:

International Standard	*Corresponding Indian Standard*
IEC QC 001001 (1981) Basic rules of the IEC quality assessment system for Electronic Components (IECQ)	IS QC 001001 (1988) Basic rules of the IEC quality assessment system for Electronic Components (IECQ) (Identical)
IEC QC 001002 (1981) Rules of procedures of the IEC quality assessment system for Electronic Components (IECQ)	IS QC 001002 (1988) Rules of procedure of the IEC quality assessment system for Electronic Components (IECQ) (Identical)

The technical committee responsible for the preparation of this standard has reviewed the provisions of the following international Publications and has decided that they are acceptable for use in conjunction with this standard:

IEC Pub 27-1 (1971) Letter symbols to be used in electrical technology, Part 1 General

IEC Pub 50 International Electrotechnical Vocabulary (I.E.V.)

IEC Pub 62 (1974) Marking codes for resistors and capacitors

IEC Pub 63 (1963) Preferred number series for resistors and capacitors

IEC Pub 68-1 (1978) Basic environmental testing procedures, Part 1: General

IEC Pub 68-2-1 (1974) Tests A: Cold

IEC Pub 68-2-2 (1974) Basic environmental testing procedures, Tests B: Dry Heat.

IEC Pub 68-2-3 (1969) Test Ca: Damp heat, Steady state

IEC Pub 68-2-6 (1970) Test Fc: Vibration (Sinusoidal)

IEC Pub 68-2-13 (1966) Test M: Low Air Pressure

IEC Pub 68-2-14 (1974) Test N: Change of Temperature

IEC Pub 68-2-17 (1978) Test Q: Sealing

IEC Pub 68-2-20 (1979) Test T: Soldering

IEC Pub 68-2-21 (1975) Test U: Robustness of terminations and integral mounting devices

IEC Pub 68-2-27 (1972) Test Ea: Shock

IEC Pub 68-2-29 (1968) Test Eb: Bump

IEC Pub 68-2-30 (1969) Test Db: Damp Heat, Cyclic (12+12-hour cycle)

IEC Pub 68-2-45 (1980) Test XA and guidance: Immersion in cleaning solvents

IEC Pub 117 Recommended graphical symbols

IEC Pub 294(1969) Measurement of the dimensions of a cylindrical component having two axial terminations

IEC Pub 384-5(1977) Fixed capacitors for use in electronic equipment:
Part 5 Sectional specification, Fixed mica dielectric direct current capacitors with a rated voltage not exceeding 3 000 V. Selection of methods of test and general requirements

IEC Pub 410 (1973) Sampling plans and procedures for inspection by attributes

IEC Pub 469-1(1974) Pulse techniques and apparatus, Part 1: Pulse terms and definitions

IEC Pub 469-2(1974) Pulse techniques and apparatus, Part 2: Pulse measurement and analysis, general considerations

ISO 3(1973) Preferred numbers — series of preferred numbers

ISO 497(1973) Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers

ISO 1000(1973) SI Units and recommendations for the use of their multiples and of certain other units

The text of Amendment No. 2 (incorporating Amendment No. 1) to IEC Pub 384-1/ QC 300000 has been incorporated.

This standard is intended primarily for use under the IECQ System. A regular Indian Standard for this component could be different, identical or similar to this standard.

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

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FIXED CAPACITORS FOR USE IN ELECTRONIC EQUIPMENT

Generic specification

SECTION ONE — SCOPE

1. Scope

This standard is applicable to fixed capacitors for use in electronic equipment.

It establishes standard terms, inspection procedures and methods of test for use in sectional and detail specifications for Qualification Approval and for Quality Assessment Systems for electronic components.

SECTION TWO — GENERAL

2. General

2.1 *Related documents*

IEC publications:

Publication 27-1: (1971)	Letter Symbols to be Used in Electrical Technology, Part 1: General.
Publication 50:	International Electrotechnical Vocabulary (I.E.V.).
Publication 62: (1974)	Marking Codes for Resistors and Capacitors.
Publication 63: (1963)	Preferred Number Series for Resistors and Capacitors. Amendment No. 1 (1967). Amendment No. 2 (1977).
Publication 68:	Basic Environmental Testing Procedures.
Publication 68-1: (1978)	Part 1: General.
Publication 68-2-1: (1974)	Tests A: Cold.
Publication 68-2-1A: (1976)	First supplement.
Publication 68-2-2: (1974)	Tests B: Dry Heat
Publication 68-2-2A: (1976)	First supplement.
Publication 68-2-3: (1969)	Test Ca: Damp Heat, Steady State.

Publication 68-2-6: (1970)	Test Fc: Vibration (Sinusoidal). Amendment No. 1 (1972).
Publication 68-2-13: (1966)	Test M: Low Air Pressure.
Publication 68-2-14: (1974)	Test N: Change of Temperature.
Publication 68-2-17: (1978)	Test Q: Sealing.
Publication 68-2-20: (1979)	Test T: Soldering.
Publication 68-2-21: (1975)	Test U: Robustness of Terminations and Integral Mounting Devices. Amendment No. 1 (1979).
Publication 68-2-27: (1972)	Test Ea: Shock.
Publication 68-2-29: (1968)	Test Eb: Bump.
Publication 68-2-30: (1969)	Test Db: Damp Heat, Cyclic (12 + 12-hour cycle).
Publication 117:	Recommended Graphical Symbols.
Publication 294: (1969)	Measurement of the Dimensions of a Cylindrical Component having Two Axial Terminations.
Publication 410: (1973)	Sampling Plans and Procedures for Inspection by Attributes.

Publication QC 001001 (1981): Basic Rules of the IEC Quality Assessment System for Electronic Components (IECQ).

Publication QC 001002 (1981): Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IECQ).

ISO publications:

ISO Standard 3: (1973)	Preferred Numbers — Series of Preferred Numbers.
ISO Standard 497: (1973)	Guide to the Choice of Series of Preferred Numbers and of Series Containing more Rounded Values of Preferred Numbers.
ISO Standard 1000: (1973)	SI Units and Recommendations for the Use of their Multiples and of Certain Other Units.

Note. — The above references apply to the current editions, except for IEC Publication 68 for which the referenced edition must be used.

2.2 *Units, symbols and terminology*

2.2.1 *General*

Units, graphical symbols, letter symbols and terminology shall, whenever possible, be taken from the following publications:

ISO Standard 1000
IEC Publication 27
IEC Publication 117
IEC Publication 50

When further items are required they shall be derived in accordance with the principles of the documents listed above.

2.2.2 *Type*

A group of components having similar design features and the similarity of whose manufacturing techniques enables them to be grouped together either for qualification approval or for quality conformance inspection.

They are generally covered by a single detail specification.

Note. — Components described in several detail specifications, may, in some cases, be considered as belonging to the same type and may therefore be grouped together for qualification approval and quality conformance inspection.

2.2.3 *Style*

A sub-division of a type, generally based on dimensional factors.

A style may include several variants, generally of a mechanical order.

2.2.4 *Grade*

A term to indicate additional general characteristics concerning the intended application, e.g. long life applications.

The term "Grade" may only be used in combination with one or more words (e.g. long life grade) and not by a single letter or number.

Figures to be added after the term "Grade" should be arabic numerals.

2.2.5 *Family (of electronic components)*

A group of electronic components which predominantly displays a particular physical attribute and/or fulfils a defined function.

2.2.6 *Sub-family (of electronic components)*

A group of components within a family manufactured by similar technological methods.

2.2.7 *D.C. capacitor*

A capacitor designed essentially for application with direct voltage.

Note — A d.c. capacitor may not be suitable for use on a.c. supplies.

2.2.8 *Polar capacitor (for electrolytic capacitors)*

A capacitor intended for use with a unidirectional voltage connected according to the polarity indication.

2.2.9 *Bipolar capacitor (for electrolytic capacitors)*

An electrolytic capacitor designed to withstand an alternating voltage and/or reversal of the applied direct voltage.

2.2.10 *A.C. capacitor*

A capacitor designed essentially for application with alternating voltages.

2.2.11 *Pulse capacitor*

A capacitor for use with pulses of current or voltage.

Note. — The definitions of I E C Publications 469-1 and 469-2 apply.

2.2.12 *Rated capacitance (C_R)*

The capacitance value for which the capacitor has been designed and which is usually indicated upon it.

2.2.13 *Category temperature range*

The range of ambient temperatures for which the capacitor has been designed to operate continuously; this is defined by the temperature limits of the appropriate category.

2.2.14 *Upper category temperature*

The maximum ambient temperature for which a capacitor has been designed to operate continuously.

2.2.15 *Lower category temperature*

The minimum ambient temperature for which a capacitor has been designed to operate continuously.

2.2.16 *Rated temperature*

The maximum ambient temperature at which the rated voltage may be continuously applied.

2.2.17 *Rated voltage (d.c.) (U_R)*

The maximum direct voltage or peak value of pulse voltage which may be applied continuously to a capacitor at any temperature between the lower category temperature and the rated temperature (see Sub-clause 2.2.16)

2.2.18 *Category voltage (U_C)*

The maximum voltage which may be applied continuously to a capacitor at its upper category temperature (see Sub-clause 2.2.14).

2.2.19 *Temperature derated voltage*

For any temperature between the rated temperature and the upper category temperature, the temperature derated voltage is the maximum voltage that may be applied continuously to a capacitor.

Note. — Information on the voltage temperature dependence at temperatures between the rated temperature and the upper category temperature should, if applicable, be given in the relevant specification.

2.2.20 *Surge voltage ratio*

The quotient of the maximum instantaneous voltage which may be applied to the terminations of the capacitor for a specified time at any temperature within the category temperature range and the rated voltage or the temperature derated voltage, as appropriate.

The number of times per hour that this voltage may be applied shall be specified.

2.2.21 *Rated ripple voltage*

The r.m.s. value of the maximum allowable alternating voltage of a specified frequency superimposed on the d.c. voltage at which the capacitor may be operated continuously at a specified temperature. The sum of the direct voltage and the peak value of the alternating voltage applied to the capacitor shall not exceed the rated voltage or temperature derated voltage as applicable.

2.2.22 *Reverse voltage (for polar capacitors only)*

A voltage applied to the capacitor terminations in the reverse polarity direction.

2.2.23 *Rated ripple current*

The r.m.s. value of the maximum allowable alternating current of a specified frequency, at which the capacitor may be operated continuously at a specified temperature.

2.2.24 *Time constant*

The product of the insulation resistance and the capacitance. It is normally expressed in seconds.

2.2.25 *Tangent of loss angle (tan δ)*

The power loss of the capacitor divided by the reactive power of the capacitor at a sinusoidal voltage of specified frequency.

2.2.26 *Self-healing*

The process by which the electrical properties of the capacitor, after a local breakdown of the dielectric, are rapidly and essentially restored to the values before the breakdown.

2.2.27 *Maximum temperature of a capacitor*

The temperature at the hottest point of its external surface.

Note. — The terminations are considered to be part of the external surface.

2.2.28 *Minimum temperature of a capacitor*

The temperature at the coldest point of its external surface.

Note. — The terminations are considered to be part of the external surface.

2.2.29 *Minimum storage temperature*

The minimum permissible ambient temperature which the capacitor shall withstand in the non-operating condition without damage.

Note. — The maximum permissible storage temperature is equal to the upper category temperature.

2.2.30 *Variation of capacitance with temperature*

The variation of capacitance with temperature can be expressed in two ways:

a) Temperature characteristic of capacitance.
b) Temperature coefficient of capacitance.

2.2.30.1 *Temperature characteristic of capacitance*

The term characterizing this property applies mainly to capacitors of which the variations of capacitance as a function of temperature, linear or non-linear, cannot be expressed with precision and certainty.

The temperature characteristic of capacitance is the maximum reversible variation of capacitance produced over a given temperature range within the category temperature range. It is expressed normally as a percentage of the capacitance related to a reference temperature of 20 °C.

2.2.30.2 *Temperature coefficient of capacitance and temperature cyclic drift of capacitance*

The terms characterizing these two properties apply to capacitors of which the variations of capacitance as a function of temperature are linear or approximately linear and can be expressed with a certain precision.

For these capacitors, the variation of capacitance for any temperature, within the category temperature range, can be analysed into two components:

Temperature coefficient of capacitance (α)

The rate of change of capacitance with temperature measured over a specified range of temperature. It is normally expressed in parts per million per degree Celsius (10^{-6}/°C).

Temperature cyclic drift of capacitance

The maximum irreversible variation of capacitance observed at room temperature during or after the completion of a number of specified temperature cycles. It is expressed normally as a percentage of the capacitance related to a reference temperature. This is normally 20 °C.

The conditions of measurement, during or after temperature cycling, a description of the temperature cycle and the number of cycles, shall be stated.

2.2.31 *Visible damage*

Visible damage which reduces the usability of the capacitor for its intended purpose.

2.2.32 *Rated a.c. load*

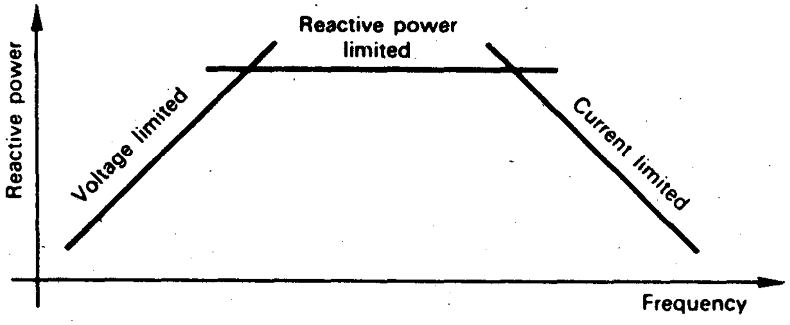
The rated load (a.c.) is the maximum sinusoidal a.c. load which may be applied continuously to the terminations of a capacitor at any temperature between the lower category temperature and the rated temperature (see Sub-clause 2.2.16). It may be expressed:

a) at low frequencies as a rated a.c. voltage;

b) at high frequencies as a rated a.c. current;

c) at intermediate frequencies as a rated reactive power.

This is shown in the following figure:



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Notes 1. — For a particular type of capacitor it may be necessary to specify one or more of the above characteristics.

2. — Capacitors within the scope of this specification are normally less than 500 var at 50-60 Hz. Low frequencies may be 50-60 Hz, 100-120 Hz, or 400 Hz. Voltages may be up to 600 V r.m.s. at 50-60 Hz. However, capacitors for filters, transmitter or converter circuits may be required to operate under power over a wide range of frequencies and up to 10 kvar at the higher frequencies with voltages up to 1 000 V r.m.s.

2.2.33 *Rated pulse load*

The rated pulse load is the maximum pulse load which may be applied at a certain pulse repetition frequency to the terminations of a capacitor at any temperature between the lower category temperature and the rated temperature (see Sub-clause 2.2.16). It may be expressed as *a)* and *b)* and any of the remaining items:

a) peak current per µF or $\frac{dv}{dt}$ (V/µs);

b) relative duration of charge and discharge periods;

c) r.m.s. current;

d) peak voltage;

e) peak reverse voltage;

f) pulse repetition frequency (see note);

g) maximum active power.

These parameters are fixed for periodic pulses.

Note. — In the case of intermittent pulses the duty cycle shall be specified. In the case of random pulses the total number expected over a given time period shall be stated.

2.2.34 *R.M.S. pulse current*

This shall be calculated in accordance with Sub-clause 2.5.2.4 of I E C Publication 469-1. In the case of intermittent or random pulses the time interval shall be chosen to correspond with the maximum temperature rise.

2.2.35 *Pulse equivalent circuit of a capacitor*

The equivalent circuit of a capacitor consists of an ideal capacitor in series with the residual inductance and the equivalent series resistance (ESR).

Note. — For pulse operation the equivalent series resistance will be similar to but not identical with the ESR measured with a sinusoidal voltage. The pulse ESR shall take into account the series of harmonics in the pulse and the variation of the losses with frequency.

2.2.36 *Temperature rise*

The temperature rise of the capacitor relative to the ambient temperature resulting from the losses in the capacitor due to operation under a.c. or pulse conditions.

2.2.37 *Insulated capacitor*

A capacitor in which all terminations of a section may be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use.

2.2.38 *Uninsulated capacitor*

A capacitor in which one or more of the terminations of a section cannot be raised to a potential different (but not less than the rated voltage) from that of any conducting surface with which the case is liable to come into contact in normal use.

2.3 *Preferred values*

2.3.1 *General*

Each sectional specification shall prescribe the preferred values appropriate to the sub-family; for rated capacitance see also Sub-clause 2.3.2

2.3.2 *Preferred values of rated capacitance*

The preferred values of rated capacitance shall be taken from the series specified in IEC Publication 63.

2.4 *Marking*

2.4.1 *General*

The sectional specification shall indicate the identification criteria and other information to be shown on the capacitor and/or packing.

The order of priority for marking small capacitors shall be specified.

2.4.2 *Coding*

When coding is used for capacitance value, tolerance or date of manufacture, the method shall be selected from those given in IEC Publication 62.

SECTION THREE — QUALITY ASSESSMENT PROCEDURES

3. Quality assessment procedures

3.1 *Qualification Approval/Quality Assessment Systems*

3.1.1 For a full Quality Assessment System the procedures of Sub-clauses 3.4 and 3.5 shall be followed.

3.1.2 For Qualification Approval without Quality Conformance Inspection (type testing only) the procedures and requirements of Sub-clauses 3.4.1 and 3.4.2*b)* may be used as appropriate, but, in any case, tests and parts of tests shall be applied in the order given in the test schedules.

3.2 *Primary Stage of Manufacture*

For fixed capacitor specifications, the primary stage shall be defined in the sectional specification.

3.3 *Structurally Similar Components*

The grouping of structurally similar components for the purpose of qualification approval and quality conformance inspection shall be prescribed in the sectional specification.

3.4 *Qualification Approval Procedures*

3.4.1 The manufacturer shall comply with:

- the general requirements of the rules of procedure governing qualification approval:
- the requirements for the primary stage of manufacture contained in Sub-clause 3.2 of this standard.

3.4.2 In addition to the requirements of Sub-clause 3.4.1, procedures *a)* or *b)* below shall apply:

a) The manufacturer shall produce test evidence of conformance to the specification requirements on three inspection lots for lot-by-lot inspection taken in as short a time as possible and one lot for periodic inspection. No major changes in the manufacturing process shall be made in the period during which the inspection lots are taken.

Samples shall be taken from the lots in accordance with IEC Publication 410 (see Appendix A). The capacitance and voltage ranges for which qualification approval is granted, are defined by the sample taken in accordance with the sampling procedures prescribed by the sectional specification.
Normal inspection shall be used, but when the sample size would give acceptance on zero defectives, additional specimens shall be taken to meet the sample size requirements to give acceptance on one defective.

b) The manufacturer shall produce test evidence to show conformance to the specification requirements on the fixed sample size test schedule given in the Sectional Specification.

The specimens taken to form the sample shall be selected at random from current production or as agreed with the National Supervising Inspectorate.

For the two procedures the sample sizes and the permissible number of defectives shall be of comparative order. The test conditions and requirements shall be the same.

3.4.3 Qualification Approval obtained as part of a Quality Assessment System, shall be maintained by regular demonstration of compliance with the requirements for quality conformance (see Sub-clause 3.5). Otherwise, this Qualification Approval must be verified by the rules for the maintenance of Qualification Approval given in the Rules of Procedure of the IEC Quality Assessment System for Electronic Components (IEC Publication QC 001002, Sub-clauses 11.5.2 and 11.5.3).

3.5 *Quality Conformance Inspection*

The blank detail specification(s) associated with the sectional specification shall prescribe the test schedule for Quality Conformance Inspection.

This schedule shall also specify the grouping, sampling and periodicity for the lot-by-lot and periodic inspection.

Inspection levels and AQL's shall be selected from those given in IEC Publication 410.

If required, more than one schedule may be specified.

3.5.1 *Certified Records of Released Lots*

When certified records of released lots are prescribed in the relevant specification and are requested by a purchaser, the following information shall be given as a minimum:

- attributes information (i.e. number of components tested and number of defective components) for tests in the sub-groups covered by periodic inspection without reference to the parameter for which rejection was made.
- variables information for the change in capacitance, for the tangent of loss angle and for the insulation resistance after the endurance test, as required in the sectional specification However the results for insulation resistance may be given by attributes only.

3.5.2 *Delayed delivery*

Fixed capacitors held for a period exceeding two years (unless otherwise specified in the sectional specification), following the release of the lot shall, before delivery, be re-examined as specified in the sectional specification.

The re-examination procedure adopted by the manufacturer's Chief Inspector shall be pproved by the National Supervising Inspectorate.

Once a "lot" has been satisfactorily re-inspected, its quality is re-assured for the specified period.

3.5.3 *Release for delivery before the completion of Group B tests*

When the conditions of IEC Publication 410 for changing to reduced inspection have been satisfied for all Group B tests, the manufacturer is permitted to release components before the completion of such tests.

3.6 *Alternative test methods*

The test and measurement methods given in the relevant specification are not necessarily the only methods which can be used. However, the manufacturer shall satisfy the National Supervising Inspectorate that any alternative methods which he may use will give results equivalent to those obtained by the methods specified. In case of dispute, for referee and reference purposes, the specified methods only shall be used.

3.7 *Unchecked parameters*

Only those parameters of a component which have been specified in a detail specification and which were subject to testing can be assumed to be within the specified limits.

It should not be assumed that any parameter not specified will remain unchanged from one component to another. Should for any reason it be necessary for (a) further parameter(s) to be controlled, then a new, more extensive, specification should be used.

The additional test method(s) shall be fully described and appropriate limits, AQL's and inspection levels specified.

SECTION FOUR — TESTS AND MEASUREMENT PROCEDURES

4. Tests and measurement procedures

4.1 *General*

The sectional and/or blank detail specification shall contain tables showing the tests to be [redacted] and the sequence in which they shall be made. The stages of each test shall be carried out in the order written. The measuring conditions shall be the same for initial and final measurements.

If national specifications within any Quality Assessment System include methods other than those specified in the above documents, they shall be fully described.

The issue and amendment status of any IEC Publication 68 test in this section is given in Sub-clause 2.1

4.2 *Standard atmospheric conditions*

4.2.1 *Standard atmospheric conditions for testing*

Unless otherwise specified, all tests and measurements shall be made under standard atmospheric conditions for testing as given in Sub-clause 5.3 of IEC Publication 68-1:

- Temperature: 15 °C - 35 °C;
- Relative humidity: 45% - 75%;
- Air pressure: 86 kPa - 106 kPa (860 mbar - 1060 mbar).

Before the measurements are made, the capacitor shall be stored at the measuring temperature for a time sufficient to allow the entire capacitor to reach this temperature. The same period as is prescribed for recovery at the end of a test is normally sufficient for this purpose.

When measurements are made at a temperature other than the specified temperature the results shall, where necessary, be corrected to the specified temperature. The ambient temperature during the measurements shall be stated in the test report. In the event of a dispute, the measurements shall be repeated using one of the referee temperatures (as given in Sub-clause 4.2.3) and such other conditions as are prescribed in this specification.

When tests are conducted in a sequence, the final measurements of one test may be taken as the initial measurements for the succeeding test.

Note. — During measurements, the capacitor shall not be exposed to draughts, direct sun-rays or other influences likely to cause error.

4.2.2 *Recovery conditions*

Unless otherwise specified, recovery shall take place under the standard atmospheric conditions for testing (Sub-clause 4.2.1).

If recovery has to be made under closely controlled conditions, the controlled recovery conditions of Sub-clause 5.4.1 of IEC Publication 68-1 shall be used.

Unless otherwise specified in the relevant specification, a duration of 1 h to 2 h shall be used.

4.2.3 *Referee conditions*

For referee purposes, one of the standard atmospheric conditions for referee tests taken from Sub-clause 5.2 of IEC Publication 68-1, as given below, shall be chosen:

Temperature	*Relative humidity*	*Air pressure*
20 ± 1 °C	63% - 67%	86 kPa - 106 kPa (860 mbar - 1060 mbar)
23 ± 1 °C	48% - 52%	86 kPa - 106 kPa (860 mbar - 1060 mbar)
25 ± 1 °C	48% - 52%	86 kPa - 106 kPa (860 mbar - 1060 mbar)
27 ± 1 °C	63% - 67%	86 kPa - 106 kPa (860 mbar - 1060 mbar)

4.2.4 *Reference conditions*

For reference purposes, the standard atmospheric conditions for reference given in Sub-clause 5.1 of IEC Publication 68-1 apply:

- Temperature: 20 °C
- Air pressure: 101.3 kPa (1013 mbar)

4.3 *Drying*

4.3.1 Unless otherwise specified in the relevant specification, the capacitor shall be conditioned for 96 ± 4 h by heating in a circulating air oven at a temperature of 55 ± 2 °C and a relative humidity not exceeding 20%.

4.3.2 The capacitor shall then be allowed to cool in a desiccator using a suitable desiccant, such as activated alumina or silica gel, and shall be kept therein from the time of removal from the oven to the beginning of the specified tests.

4.4 *Visual examination and check of dimensions*

4.4.1 *Visual examination*

The condition, workmanship and finish shall be satisfactory, as checked by visual examination (see Sub-clause 2.2.31).

Marking shall be legible, as checked by visual examination. It shall conform with the requirements of the detail specification.

4.4.2 *Dimensions (gauging)*

The dimensions indicated in the detail specification as being suitable for gauging shall be checked, and shall comply with the values prescribed in the detail specification.

When applicable, measurements shall be made in accordance with IEC Publication 294.

4.4.3 *Dimensions (detail)*

All dimensions prescribed in the detail specification shall be checked and shall comply with the values prescribed.

4.5 *Insulation resistance*

4.5.1 Before this measurement is made, the capacitors shall be fully discharged.

4.5.2 Unless otherwise specified in the relevant specification, the insulation resistance shall be measured, at the voltage specified below.

Voltage rating of capacitor	Measuring voltage
U_R or U_C < 10 V	U_R or U_C ± 10%
10 V ≤ U_R or U_C < 100 V	10 ± 1 V*
100 V ≤ U_R or U_C < 500 V	100 ± 15 V
500 V ≤ U_R or U_C	500 ± 50 V

* When it can be demonstrated that the voltage has no influence on the measuring result, or that a known relationship exists, measurement can be performed at voltages up to the rated or category voltage (10 V shall be used in case of dispute, unless otherwise specified by the sectional specification).

U_R is the rated voltage for use in defining the measuring voltage to be used under standard atmospheric conditions for testing.

U_C is the category voltage for use in defining the measuring voltage to be used at the upper category temperature.

4.5.3 The insulation resistance shall be measured between the measuring points defined in Table I, specified in the relevant specification.

Test A, between terminations, applies to all capacitors, whether insulated or not.

Test B, internal insulation, applies to insulated capacitors in uninsulated metal cases and to insulated and uninsulated multiple-section capacitors.

Test C, external insulation, applies to insulated capacitors in non-metallic cases or in insulated metal cases. For this test, the measuring voltage shall be applied using one of the three following methods as specified in the relevant specification:

4.5.3.1 *Foil method*

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm can be maintained between the foil and the terminations. If this minimum distance cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm.

For capacitors with unidirectional terminations a minimum distance of 1 mm shall be maintained between the edge of the foil and each termination.

4.5.3.2 *Method for capacitors with mounting devices*

The capacitor shall be mounted in its normal manner on a metal plate, which extends at least 12.7 mm (0.5 in) in all directions beyond the mounting face of the capacitor.

4.5.3.3 *V-block method*

The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned in accordance with the following:

a) For cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block.

b) For rectangular capacitors: the capacitor shall be positioned in the bloc so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the terminations at its emergence from the capacitor body shall be ignored.

4.5.4 The insulation resistance shall be measured after the voltage has been applied for 1 min ± 5 s unless otherwise prescribed in the detail specification.

TABLE I

Measuring points

Tests	Applicable to:	1) Single section capacitors	2) Multiple-section capacitors having a common termination for all sections	3) Multiple-section capacitors having no common termination
A. Between terminations	All capacitors	1*a)* Between terminations	2*a)* Between each of the terminations and the common termination	3*a)* Between terminations of each section
B. Internal insulation	Insulated single and multiple-section capacitors in uninsulated metal cases (1*b)*, 2*b)*, 3*b)*)	1*b)* Between terminations connected together and the case	2*b)* Between all terminations connected together and the case	3*b)* Between all terminations connected together and the case
	Insulated and uninsulated multiple-section capacitors (2*c)* and 3*c)*)		2*c)* Between the non-common termination of each section and all the other terminations connected together	3*c)* Between the terminations of separate sections, the two terminations of each section being connected together
C. External insulation	Insulated capacitors in non-metallic cases or in insulated metal cases	1*c)* Between the two terminations connected together and, as appropriate, the metal foil, the metal plate of the metal V-block	2*d)* Between all terminations connected together and, as appropriate: the metal foil, the metal plate or the V-block	3*d)*

4.5.5 When prescribed by the detail specification the temperature at which the measurement is made shall be noted. If this temperature differs from 20 °C a correction shall be made to the measured value by multiplying the value by the appropriate correction factor prescribed in the sectional specification.

4.5.6 The relevant specification shall prescribe:

a) The measuring points and the measuring voltage corresponding to each of these tests points.

b) The method of applying the voltage (one of the methods described in Sub-clauses 4.5.3.1, 4.5.3.2 or 4.5.3.3).

c) Time of electrification if other than 1 min.

d) Any special precautions to be taken during measurements.

e) Any correction factors required for measurement over the range of temperatures covered by the standard atmospheric conditions for testing.

f) The temperature of measurement if other than the standard atmospheric conditions for testing.

g) The minimum value of insulation resistance for the various measuring points (see Table I).

4.6 *Voltage proof*

The test prescribed below is a d.c. test. When the relevant specification prescribes an a.c. test, the test circuit shall be prescribed by this specification.

4.6.1 *Test circuit* (for the test between terminations)

The test circuit shall be such that the conditions relating to the charging and discharging currents and the time constant for charging, prescribed in the relevant specification, are complied with.

The Figure 1 specifies the characteristics of a suitable test circuit:

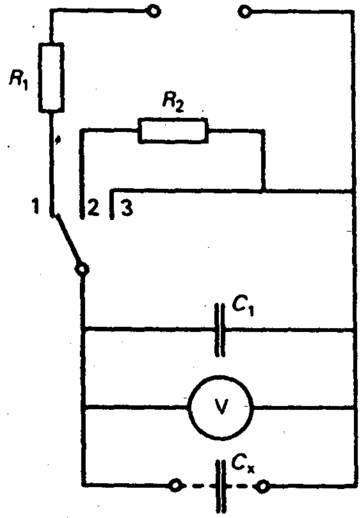


FIG. 1 Voltage proof test circuit

Note. — The capacitor C_1 may be omitted for the testing of certain types of capacitors. This should be stated in the sectional specification.

The resistance of the voltmeter shall be not less than 10 000 Ω/V.

The resistor R_1 includes the internal resistance of the voltage source.

The resistances R_1 and R_2 shall have a value sufficient to limit the charging and discharging current to the value prescribed in the relevant specification.

The capacitance of capacitor C_1 shall be not less than ten times the capacitance of the capacitor under test.

If applicable the time constant $R_2 \cdot (C_x + C_1)$ shall be less than or equal to the value prescribed in the relevant specification.

4.6.2 *Test*

Depending on the case, the test comprises one or more parts in accordance with Table 1 and the requirements of the relevant specification.

4.6.2.1 *Test A — Between terminations*

Test points: *1a)*, *2a)*, *3a)* of Table 1 in accordance with the requirements of the relevant specification.

Procedure

With the switch in position 2, the two terminals at the top of the diagram are connected to a variable d.c. supply of sufficient power adjusted to the required test voltage.

The capacitor to be tested (C_x) is connected to the test circuit as indicated in the diagram.

The switch is then moved to position 1 so as to charge capacitors C_1 and C_x via R_1.

The switch remains in this position for the time specified after the test voltage has been reached.

The capacitors C_1 and C_x are then discharged through R_2 by moving the switch to position 2. As soon as the voltmeter reading has fallen to zero the capacitors are short-circuited by moving the switch to position 3 and the capacitor C_x is disconnected.

4.6.2.2 *Test B — Internal insulation*

Test points: 1*b)*, 2*b)*, 2*c)*, 3*b)*, 3*c)* of **Table I** in accordance with the requirements of the relevant specification

Procedure

The specified test voltage is applied instantaneously via the internal resistance of the power supply for the time specified in the relevant specification. For point 2*c)* use the test circuit and the procedure indicated for the test between terminations (Sub-clauses 4.6.1 and 4.6.2.1)

4.6.2.3 *Test C — External insulation* (applicable only to insulated capacitors in non-metallic case or in insulated metal case).

Test points: 1*c)*, 2*d)* or 3*d)*, using one of the three following methods for the application of the voltage in accordance with the requirements of the relevant specification.

Foil method

A metal foil shall be closely wrapped around the body of the capacitor.

For capacitors with axial terminations this foil shall extend beyond each end by not less than 5 mm, provided that a minimum distance of 1 mm/kV can be maintained between the foil and the terminations. If this minimum cannot be maintained, the extension of the foil shall be reduced by as much as is necessary to establish the distance of 1 mm/kV of test voltage.

For capacitors with unidirectional termination, a minimum distance of 1 mm/kV shall be maintained between the edge of the foil and each termination.

In no case the distance between the foil and the terminations shall be less than 1 mm.

Method for capacitors with mounting devices

The capacitor shall be mounted in its normal manner on a metal plate which extends by not less than 12.7 mm (0.5 in) in all directions, beyond the mounting face of the capacitor.

V-block method

The capacitor shall be clamped in the trough of a 90° metallic V-block of such size that the capacitor body does not extend beyond the extremities of the block.

The clamping force shall be such as to guarantee adequate contact between the capacitor and the block.

The capacitor shall be positioned in accordance with the following:

a) For cylindrical capacitors: the capacitor shall be positioned in the block so that the termination furthest from the axis of the capacitor is nearest to one of the faces of the block.

b) For rectangular capacitors: the capacitor is positioned in the block so that the termination nearest the edge of the capacitor is nearest to one of the faces of the block.

For cylindrical and rectangular capacitors having axial terminations any out-of-centre positioning of the termination at its emergence from the capacitor body shall be ignored.

Procedure

The specified test voltage is applied instantaneously through the internal resistance of the power source for the time specified in the relevant specification.

4.6.3 *Requirements*

For each of the specified test points there shall be no sign of breakdown or flashover during the test period.

4.6.4 Repeated application of the voltage proof test may cause permanent damage to the capacitor and should be avoided as far as possible.

4.6.5 The relevant specification shall prescribe:

a) The test points (see Table I) and the test voltage corresponding to each of these points.

b) For the external insulation test (Test C): the method of applying the test voltage (one of the methods described in Sub-clause 4.6.2.3).

c) The time for which the voltage is applied.

d) The maximum charging and discharging currents.

e) When applicable, the maximum value of the time constant for charging (R_1 $(C_1 + C_x)$).

4.7 *Capacitance*

4.7.1 The capacitance shall be measured at one of the following frequencies unless otherwise prescribed by the relevant specification:

Electrolytic capacitors: 100 Hz to 120 Hz

Other capacitors: $C_R \leq 1$ nF: 100 kHz, 1 MHz or 10 MHz (1 MHz shall be reference)
1 nF $< C_R \leq 10$ µF: 1 kHz or 10 kHz (1 kHz shall be reference)
$C_R > 10$ µF: 50 Hz (60 Hz) or 100 Hz (120 Hz)

The tolerance on all frequencies for measuring purpose shall not exceed ±20%.

The measuring voltage shall not exceed 3% of U_R or 5 V, whichever is the smaller, unless otherwise prescribed in the relevant specification.

4.7.2 The accuracy of the measuring equipment shall be such that the error does not exceed:

a) for absolute capacitance measurements: 10% of the rated capacitance tolerance or 2% absolute, whichever is the smaller;

b) for measurement of variation of capacitance: 10% of the specified maximum change of capacitance.

In neither of cases *a)* and *b)* need the accuracy be better than the minimum absolute measurement error (e.g. 0.5 pF) prescribed in the relevant specification.

4.7.3 The relevant specification shall prescribe:

a) the temperature for measurement if other than the standard atmospheric conditions for testing;

b) the frequencies for measurement and the capacitance range over which they apply, if different from those specified in Sub-clause 4.7.1:

c) the absolute measurement error, when applicable (e.g. 0.5 pF);

d) measuring voltage if different from those specified in Sub-clause 4.7.1;

e) the applied polarizing voltage, when applicable.

4.8 *Tangent of loss angle*

4.8.1 The tangent of loss angle shall be measured under the same conditions as those given for the measurement of capacitance at one or more frequencies taken from the list of Sub-clause 4.7.1, as prescribed in the relevant specification.

4.8.2 Unless otherwise specified in the sectional specification, the measuring method shall be such that the error does not exceed 10% of the specified value or 0.0001, whichever is the greater.

4.9 *Leakage current*

4.9.1 Before this measurement is made, the capacitors shall be fully discharged.

4.9.2 The leakage current shall be measured, unless otherwise prescribed in the relevant specification, using the direct voltage (U_R or U_C) appropriate to the test temperature, after a maximum electrification period of 5 min. The full five minute electrification need not be applied if the specified leakage current limit is reached in a shorter time.

4.9.3 A steady source of power such as a regulated power supply shall be used.

4.9.4 The measurement error shall not exceed ±5% or 0.1 μA, whichever is the greater.

4.9.5 When prescribed in the relevant specification, a 1000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current.

4.9.6 The relevant specification shall prescribe:

a) the leakage current limit at a reference temperature of 20 °C, and at other specified temperatures;

b) when necessary, the correction factor, if the measurements are made at a temperature other than 20 °C, but within the range of temperatures covered by the standard atmospheric conditions for testing;

c) electrification time if different from 5 min

d) whether or not a 1 000 Ω protective resistor shall be placed in series with the capacitor to limit the charging current as defined in Sub-clause 4.9.5.

4.10 *Impedance*

Impedance shall be measured by the voltmeter-ammeter method according to the circuit of Figure 2 , or equivalent.

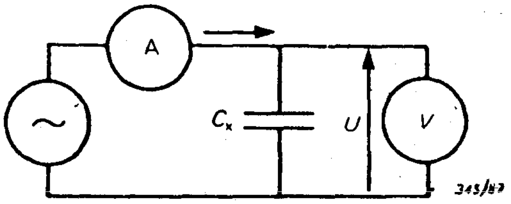


FIG. 2 — Schematic diagram of the measuring circuit.

The impedance Z_x of the capacitor C_x is given by

$$Z_x = \frac{U}{I}$$

The frequency of the measuring voltage shall preferably be chosen from the following values:

50 Hz, 60 Hz, 100 Hz, 120 Hz, 1 kHz, 10 kHz, 100 kHz, 1 MHz and 10 MHz.

The accuracy of the measuring equipment shall be such that the error does not exceed 10% of the requirement, unless otherwise specified in the relevant specification.

Note — At frequencies above 120 Hz precautions are necessary to avoid errors arising from stray currents. The current flowing through the capacitor should be limited so that the measuring result is not significantly affected by the rise of the temperature of the capacitor.

The relevant specification shall prescribe:

a) The frequency of measurement.

b) The temperature(s) at which measurements shall be made.

c) The limits of impedance, or ratio of impedances measured at different temperatures.

4.11 *Inductance or self-resonant frequency*

4.11.1 *Self-resonant frequency* (f_r)

For this measurement three methods are described. The first method is for general application; the other methods may be particularly suitable for measuring certain types of capacitors having low capacitance.

The accuracy of the measuring equipment shall be such that the error does not exceed 10% of the requirement, unless otherwise specified in the relevant specification.

4.11.1.1 *Method 1*

Using the impedance measuring method of Sub-clause 4.10 and a variable frequency source, the lowest frequency shall be determined at which the impedance passes through a minimum. This is the self-resonant frequency.

Note. When it is difficult to determine precisely the frequency at which the impedance is at a minimum, then use may be made of a phase-meter to compare the phase of the voltage across the capacitor with the phase of the voltage across a low-inductance resistor connected in series with the capacitor. The resonant frequency is then the frequency when there is no phase difference. A Q-meter may be used for this purpose.

4.11.1.2 *Method 2*

For this measuring method use shall be made of an absorption oscillator-wavemeter (grid dip meter).

Mounting

4.11.1.2.1 *Capacitors with terminations for general use*

Four capacitors of nearly equal value and configuration shall be soldered in series at right angles to form a closed loop.

The wires shall be of the specified length and no additional wiring or connections shall be employed (see Figure 3). This loop shall be coupled as loosely as possible to an absorption oscillator-wavemeter and the resonant frequency shall then be determined.

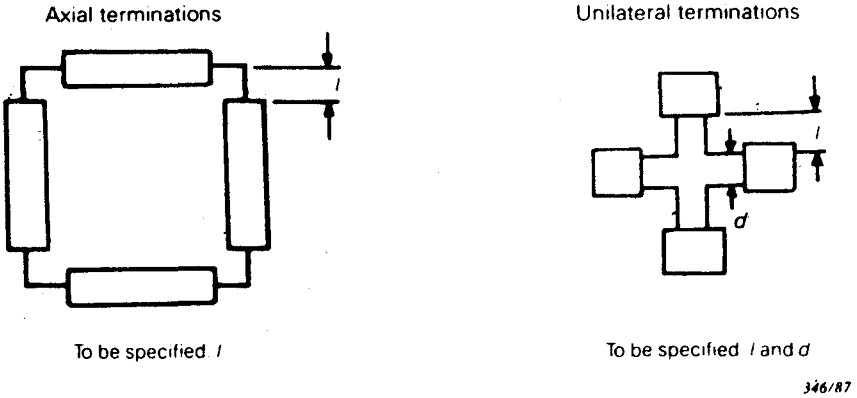


FIGURE 3

4.11.1.2.2 *Capacitors with terminations for printed circuit use*

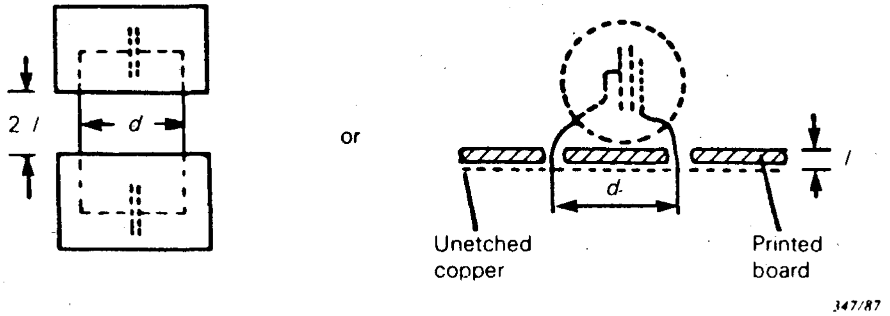
To determine the resonant frequency under the conditions of being mounted on a printed circuit board and where the configuration of the case and/or the terminations does not permit to form a four-capacitor loop correctly, the loop shall be formed of two (nearly) identical capacitors with straight terminations of specified length (see Figure 4).

The second capacitor may be substituted by its mirror image on a conductive plane in the following way:

A copperclad unetched sheet of printed circuit base material, the edges of which are at least three times as long as the maximum dimension of the capacitor, is drilled in its centre to accommodate the capacitor in its normal way.

The relevant specification shall prescribe the details of mounting. The capacitor is soldered in place with the capacitor being short-circuited by the copper laminate. Then the capacitor is coupled to the search coil and measured as in Sub-clause 4.11.1.2.4.

Note. — Metal-cased capacitors may necessitate special arrangements for coupling, which shall be prescribed in the relevant specification.



To be specified: *l* and *d*
(*l* to be measured from the seating plane)

FIGURE 4

4.11.1.2.3 *Description of the method*

The absorption oscillator-wavemeter is a variable frequency L-C oscillator with the inductor formed as an external search coil. When the search coil is coupled into another resonant circuit, power is absorbed causing a change in the mean grid (Gate on FET's) voltage.

This is monitored and hence "dips" at the resonant frequency of the coupled circuit.

This coupled circuit consists of four capacitors mounted as described in Sub-clause 4.11.1.2.1 and connected in series to minimize the mutual inductance.

A typical diagram showing the use of an absorption oscillator wavemeter is given in Figure 5.

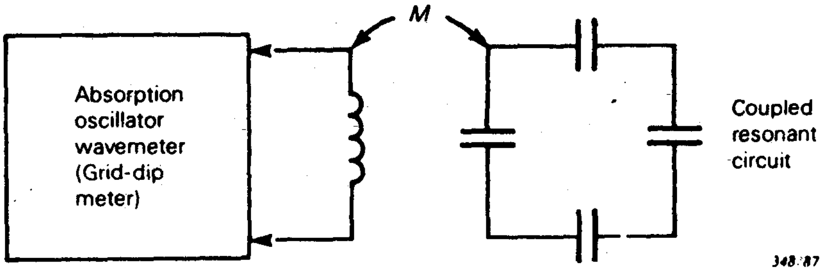


FIGURE 5

4.11.1.2.4 *Use of the wavemeter*

With the search coil of the wavemeter close to the capacitors under investigation, the resonant frequency is approached from a lower frequency. Dips should be checked by moving the wavemeter away from the capacitors (reducing the absorbed power) to make sure the dip is not due to internal effects of the wavemeter. The resonant frequency should be measured with as loose coupling as is practical to avoid pulling the oscillator.

4.11.1.2.5 *Requirements*

The resonant frequency shall not exceed the limits prescribed by the relevant specification.

4.11.1.3 *Method 3*

This method is particularly suitable for capacitors of low capacitance and with a self-resonant frequency within Q-meter operating range. Using a Q-meter and the circuit shown in Figure 6, the lowest frequency shall be determined at which the same resonant frequency is obtained, whether the capacitor shorting strap is in place or not. This frequency can be shown equal to the self-resonant frequency of the capacitor.

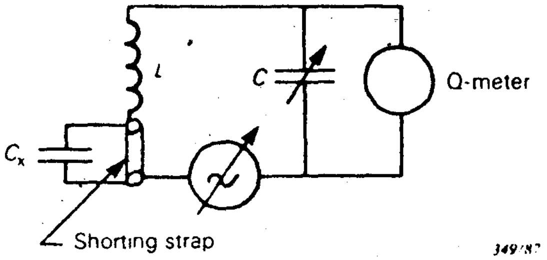


FIG. 6. Schematic diagram of the measuring circuit.

4.11.2 *Inductance*

The series inductance L_x of a capacitor is calculated from the measured self-resonant frequency f_r of the capacitor using the formula given below:

$$L_x = \frac{1}{4\pi^2 f_r^2 C_x}$$

where C_x is the capacitance of the capacitor measured in accordance with Sub-clause 4.7 and the requirements of the relevant sectional specification.

4.11.3 The relevant specification shall prescribe:

a) which test method is preferred

b) the lead length of the capacitor to be employed in the measurement

c) any special mounting arrangement

d) the limits of series inductance or self-resonant frequency.

4.12 *Outer foil termination*

4.12.1 The correct indication of the termination which is connected to the outside metal foil shall be checked in such a way that the capacitor is not damaged.

4.12.2 A suitable method is given in Figure 7.

4.12.2.1 The frequency of the generator may be from 50 Hz to a few thousand hertz and shall be so chosen as to give a clear result of measurement, the most appropriate value being dependent on the type of capacitor under test.

The voltage shall be of the order of 10 V.

The voltmeter shall have an input impedance of not less than 1 MΩ.

The stray capacitance of the wiring shall be kept low.

4.12.2.2 With the switch in position 1, the deflection of the voltmeter shall be markedly less than the switch in position 2.

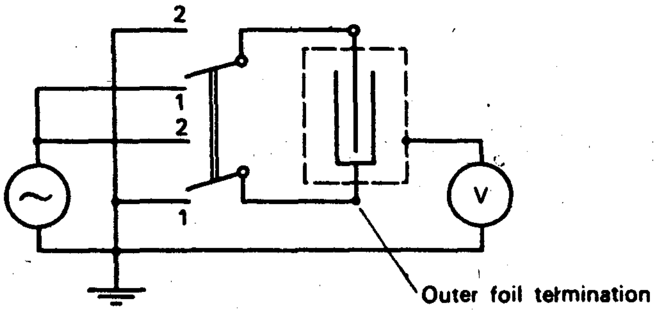


FIG. 7. — Test circuit.

4.13 *Robustness of terminations*

The capacitors shall be subjected to Tests Ua_1, Ub, Uc, and Ud of IEC Publication 68-2-21 (1975), as applicable.

4.13.1 *Test Ua_1 — Tensile*

The force applied shall be:

- for terminations other than wire terminations: 20 N;
- for wire terminations, see table below.

Nominal cross-sectional area (mm²)	Corresponding diameter for circular-section wires (mm)	Force (N)
$S \leq 0.05$	$d \leq 0.25$	1
$0.05 < S \leq 0.07$	$0.25 < d \leq 0.3$	2.5
$0.07 < S \leq 0.2$	$0.3 < d \leq 0.5$	5
$0.2 < S \leq 0.5$	$0.5 < d \leq 0.8$	10
$0.5 < S \leq 1.2$	$0.8 < d \leq 1.25$	20
$1.2 < S$	$1.25 < d$	40

4.13.2 *Test Ub — Bending (half of the terminations)*

Method 1: Two consecutive bends shall be applied in each direction. This test shall not apply if, in the detail specification, the terminations are described as rigid.

4.13.3 *Test Uc — Torsion (other half of the terminations)*

Method A, severity 2 (two successive rotations of 180°) shall be used.

This test shall not apply if in the detail specification the terminations are described as rigid and to components with unidirectional terminations designed for printed wiring applications.

4.13.4 *Test Ud — Torque (for terminations with threaded studs or screws and for integral mounting devices)*

Nominal thread diameter (mm)		2.6	3	3.5	4	5	6
Torque (N.m)	Severity 1	0.4	0.5	0.8	1.2	2.0	2.5
	Severity 2	0.2	0.25	0.4	0.6	1.0	1.25

4.13.5 *Visual examination*

After each of these tests the capacitors shall be visually examined. There shall be no visible damage.

4.14 *Resistance to soldering heat*

4.14.1 When prescribed by the relevant specification, the capacitors shall be dried using the method of Sub-clause 4.3.

The capacitors shall be measured as prescribed in the relevant specification.

4.14.2 Unless otherwise stated in the relevant specification, the capacitors shall undergo Test Tb of IEC Publication 68-2-20 (1979) with the following requirements:

a) All capacitors except those of Item *b)* below:

Method 1A, with a duration of 5 s or 10 s, as specified in the detail specification.

Depth of immersion from the seating plane: $2\,^{0}_{0.5}$ mm, using a thermal insulating screen of 1.5 ± 0.5 mm thickness.

b) Capacitors not designed for use on printed boards as indicated by the detail specification:

Method 1B
Depth of immersion from the component body: $3.5\,^{0}_{0.5}$ mm

The period of recovery shall be not less than 1 h nor more than 2 h, unless otherwise specified by the detail specification.

4.14.3 When the test has been carried out the capacitors shall be visually examined.

There shall be no visible damage and the marking shall be legible.

The capacitors shall then be measured as prescribed in the relevant specification.

4.15 *Solderability*

4.15.1 Capacitors shall be subject to Test Ta of IEC Publication 68-2-20 (1979), either using the solder bath method (Method 1) or the soldering iron method (Method 2) or the solder globule method (Method 3) as prescribed by the detail specification.

4.15.2 When the solder bath method (Method 1) is specified, the following requirements apply:

4.15.2.1 *Test conditions*

Bath temperature: 235 ± 5 °C.

Immersion time: 2.0 ± 0.5 s.

Depth of immersion (from the seating plane or component body):

a) All capacitors except those of *b)* below:
$2.0\,^{0}_{0.5}$ mm, using a thermal insulating screen of 1.5 ± 0.5 mm thickness.

b) Capacitors indicated by the detail specification as being not designed for use on printed boards: $3.5\,^{0}_{0.5}$ mm.

4.15.2.2 The terminations shall be examined for good tinning as evidenced by free flowing of the solder with wetting of the terminations.

4.15.2.3 When the solder bath method is not applicable, the relevant specification shall define both the method, test conditions and the requirements.

Note. — When the solder globule method is used, the requirement shall include the soldering time.

4.16 *Rapid change of temperature*

4.16.1 The measurements prescribed in the relevant specification shall be made.

4.16.2 The capacitors shall be subjected to Test Na of IEC Publication 68-2-14 (1974), using the degree of severity as prescribed in the relevant specification.

4.16.3 After recovery the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.17 *Vibration*

4.17.1 The measurements prescribed in the relevant specification shall be made.

4.17.2 The capacitors shall be subjected to Test Fc of IEC Publication 68-2-6 (1970), using the mounting method and the degree of severity prescribed in the relevant specification.

4.17.3 When specified in the detail specification, during the last 30 minutes of the vibration test in each direction of movement, an electrical measurement shall be made to check intermittent contacts or open or short circuit.

The duration of the measurement shall be the time needed for one sweep of the frequency range from one frequency extreme to the other.

4.17.4 After the test the capacitors shall be visually examined. There shall be no visible damage. When capacitors are tested as specified in Sub-clause 4.17.3, there shall be no intermittent contact greater than or equal to 0.5 ms, nor open or short circuit.

4.17.5 The measurements prescribed in the relevant specification shall then be made.

4.18 *Bump*

4.18.1 The measurements prescribed in the relevant specification shall be made.

4.18.2 The capacitors shall be subjected to Test Eb of IEC Publication 68-2-29 (1968) using the mounting method and the degree of severity prescribed in the relevant specification.

4.18.3 After the test the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.19 *Shock*

4.19.1 The measurements prescribed in the relevant specification shall be made.

4.19.2 The capacitors shall be subjected to Test Ea of IEC Publication 68-2-27 (1972) using the mounting method and the severity prescribed in the relevant specification.

4.19.3 After the test the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.20 *Container sealing*

The capacitors shall be subjected to the procedure of the appropriate method of Test Q of IEC Publication 68-2-17 (1978) as prescribed in the relevant specification.

4.21 *Climatic sequence*

In the climatic sequence, an interval of a maximum of 3 days is permitted between any of the tests, except that the cold test shall be applied immediately after the recovery period for the first cycle of the damp heat, cyclic, Test Db.

4.21.1 *Initial measurements*

The measurements prescribed in the relevant specification shall be made.

4.21.2 *Dry heat*

The capacitors shall be subjected to Test Ba of IEC Publication 68-2-2 (1974) for 16 h, using the degree of severity of the upper category temperature, as prescribed in the detail specification.

While still at the specified high temperature and at the end of the period of high temperature, the measurements prescribed in the relevant specification shall be made.

After specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.

4.21.3 *Damp heat, cyclic, Test Db, first cycle*

The capacitors shall be subjected to Test Db of IEC Publication 68-2-30 (1969) for one cycle of 24 h, using a temperature of 55 °C (Severity b).

After recovery the capacitors shall be subjected immediately to the cold test.

4.21.4 *Cold*

The capacitors shall be subjected to Test Aa of IEC Publication 68-2-1 (1974) for 2 h, using the degree of severity of the lower category temperature, as prescribed in the relevant specification.

While still at specified low temperature and at the end of the period of low temperature, the measurements prescribed in the relevant specification shall be made

After the specified conditioning, the capacitors shall be removed from the chamber and exposed to standard atmospheric conditions for testing for not less than 4 h.

4.21.5 *Low air pressure*

The capacitors shall be subjected to Test M of IEC Publication 68-2-13 (1966) using the appropriate degree of severity prescribed in the relevant specification. The duration of the test shall be 10 min, unless otherwise stated in the relevant specification.

The relevant specification shall prescribe:

a) duration of test, if other than 10 min;

b) temperature;

c) degree of severity.

While at the specified low pressure, the rated voltage shall be applied for the last 1 min of the test period, unless otherwise prescribed in the relevant specification.

During and after the test there shall be no evidence of permanent breakdown, flashover, harmful deformation of the case or seepage of impregnant.

4.21.6 *Damp heat, cyclic, Test Db, remaining cycles*

The capacitors shall be subjected to Test Db of IEC Publication 68-2-30 (1969) for the following number of cycles of 24 h as indicated in the table below, at a temperature of 55 °C (Severity b).

Categories	Number of cycles
- - /56	5
- - /21	1
- - /10	1
- - /04	None

4.21.7 *Final measurements*

After the prescribed recovery, the measurements prescribed in the relevant specification shall be made.

4.22 *Damp heat, steady state*

4.22.1 The measurements prescribed in the relevant specification shall be made.

4.22.2 The capacitors shall be subjected to Test Ca of IEC Publication 68-2-3 (1969), using the degree of severity corresponding to the climatic category of the capacitor as indicated in the detail specification. When specified in the blank detail specification, the detail specification may specify the application of a polarizing voltage during the whole period of damp heat conditioning. With the exception of electrolytic capacitors, within 15 min after removal from the test chamber, the voltage proof test of Sub-clause 4.6 shall be carried out at Test point A only, using the rated voltage, unless otherwise specified in the detail specification.

4.22.3 After recovery the capacitors shall be visually examined. There shall be no visible damage.

The measurements prescribed in the relevant specification shall then be made.

4.23 *Endurance*

4.23.1 *Initial measurements*

The measurements prescribed in the relevant specification shall be made.

4.23.2 The capacitors shall be submitted to the endurance test. The tests of IEC Publication 68-2-2 (1974) apply as follows:

a) d.c. tests — Test Ba;

b) a.c. tests — Test Ba or Bc as applicable;

c) pulse tests — Test Ba or Bc as applicable.

The test specimens may be inserted in the oven at any temperature between room ambient temperature and the specified oven temperature, but the voltage shall not be applied to the capacitor before it has reached the oven temperature.

4.23.3 The relevant specification shall prescibe:

a) duration of the test (e.g. hours or number of pulses);

b) test temperature (e.g. room, rated or upper category temperature);

c) voltage or current to be applied (see also Sub-clause 4.23.4).

When capacitors have to meet additional requirement for electric shock hazard protection, additional test conditions for endurance testing (e.g. pulse voltage application) shall be prescribed in the relevant specification.

4.23.4 Unless otherwise specified in the relevant specification the voltage to be applied during the test shall be selected from the following:

a) d.c. tests.

The test shall be carried out at a multiplying factor times the rated voltage (d.c.) at temperatures up to the rated temperature. The test temperature and the value of the multiplying factor shall be specified in the relevant specification. For tests at upper category temperature the derating factor for the voltage shall be given as well.

b) a.c. tests (sinusoidal voltage).

The test shall be made at 50-60 Hz and at a multiplying factor times the rated voltage (a.c.) (see Sub-clause 2.2.32 *a)*) at temperatures up to the rated temperature or at the upper category temperature with a derating factor for the voltage. The test temperature and the value of the multiplying factor/derating factor for the voltage shall be specified in the relevant specification.

c) a.c. tests (sinusoidal current).

This test shall be made with a current applied in accordance with Sub-clause 2.2.32 *b)*. The test temperature, the value of current and frequency shall be specified in the relevant specification.

Note. — To facilitate testing the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

d) sinusoidal a.c. tests (reactive power)

This test shall be made with reactive power in accordance with Sub-clause 2.2.32 *c)*. The test temperature, the value of the reactive power, and the frequency shall be specified in the relevant specification.

Note. — To facilitate testing the test may be made with a voltage of specified frequency applied to a group of capacitors in parallel or in series/parallel.

A thermal stability test (see Sub-clause 4.30) may constitute an alternative to this test. The test to be carried out shall be specified in the detail specification.

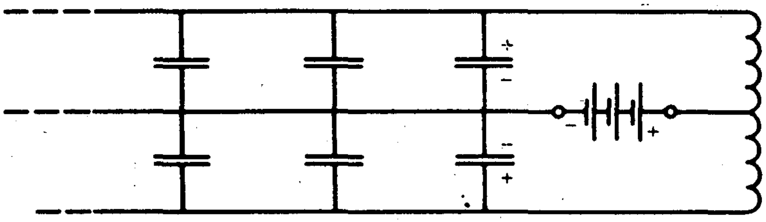
e) pulse tests.

The test shall be made with pulses applied in accordance with Sub-clause 2.2.33 and as specified in the relevant specification. Guidance for pulse tests is given in Appendix C.

f) sinusoidal a.c. or pulse tests with superimposed d.c.

Tests *b)* to *e)* may be carried out with superimposed d.c. as required by the relevant specification. (See also Sub-clause 2.2.21).

An example of a test circuit suitable for electrolytic capacitors is as follows:



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4.23.5 The capacitors shall be placed in the test chamber in such a manner that:

a) for heat dissipating capacitors no capacitor is within 25 mm of any other capacitor.

b) for non-heat dissipating capacitors no capacitor is within 5 mm of any other capacitor.

4.23.6 After the specified period, the capacitors shall be allowed to cool to standard atmospheric conditions for testing.

4.23.7 The capacitors shall then be visually examined.

4.23.8 The measurements prescribed in the relevant specification shall then be made. A capacitor shall be considered to have failed when the requirements of the relevant specification during or at the end of the test are not satisfied.

4.24 *Variation of capacitance with temperature*

4.24.1 *Static method*

4.24.1.1 Measurements of capacitance shall be made under the conditions prescribed in the relevant specification.

4.24.1.2 The capacitor shall be maintained at each of the following temperatures in turn:

a) 20 ± 2 °C;

b) lower category temperature ±3 °C;

c) intermediate temperatures, if required by the detail specification;

d) 20±2 °C;

e) intermediate temperatures, if required by the detail specification;

f) upper category temperature ±2 °C;

g) 20±2 °C.

If required for a particular type of capacitor, the relevant specification shall prescribe whether thermal shock is to be avoided or whether a maximum rate of change of temperature shall be specified.

4.24.1.3 Capacitance measurements shall be made at each of the temperatures specified above after the capacitor has reached thermal stability.

The condition of thermal stability is judged to be reached when two readings of capacitance taken at an interval of not less than 5 min do not differ by an amount greater than that which can be attributed to the measuring apparatus.

The measurement of the actual temperature must be made with a precision compatible with the requirements of the detail specification.

Care must be taken during measurements to avoid condensation or frost on the surface of the capacitors.

4.24.1.4 For the lot-by-lot quality conformance testing, the detail specification may prescribe a reduced procedure, for example measurements *d)*, *f)* and *g)* covering the temperature range from 20 °C to the upper category temperature.

4.24.2 *Dynamic method*

As an alternative to the static method of Sub-clauses 4.24.1.2 and 4.24.1.3, a dynamic plotting method may be employed. The capacitors shall be subjected to a slowly varying temperature.

A temperature-sensitive device shall be embedded in a dummy capacitor to be included with the capacitor under test in a manner that will ensure that the measured temperature is the same as that occurring in the capacitor under test. The capacitance shall be measured using a self-balancing bridge or comparator.

The output of the bridge or comparator shall be coupled to the "Y" axis of a plotting table.

The output of the temperature sensing device shall be coupled to the "X" axis of a plotting table.

The temperature shall be varied slowly enough to produce a uniform curve with no loop at the lower or upper category temperature. The temperature shall be varied subsequently from 20 °C to the lower category temperature, to the upper category temperature and to 20 °C. Two cycles shall be carried out.

This method may be employed only when it can be demonstrated that the results are the same as for the method employing stabilized temperatures.

In case of dispute, the static method shall be used.

4.24.3 *Methods of calculation*

C_0 = capacitance measured at point *d)* of Sub-clause 4.24.1.2

θ_0 = temperature measured at point *d)* of Sub-clause 4.24.1.2

C_i = capacitance measured at the test temperature, other than at points *a)*, *d)* and *g)*

θ_i = temperature measured on test

4.24.3.1 *Temperature characteristic of capacitance*

The variation of capacitance as a function of temperature shall be calculated for all the values of C_i as follows:

$$\frac{\Delta C}{C_0} = \frac{C_i - C_0}{C_0}$$

The variation of capacitance is normally expressed in per cent.

4.24.3.2 *Temperature coefficient of capacitance and temperature cyclic drift of capacitance*

a) Temperature coefficient of capacitance (α)

Temperature coefficient of capacitance (α) shall be calculated for all the values of C_i as follows:

$$\alpha_i = \frac{C_i - C_0}{C_0\ (\theta_i - \theta_0)}$$

The temperature coefficient is normally expressed in parts per million per degree Celsius (10^{-6}/°C).

b) Temperature cyclic drift of capacitance

The temperature cyclic drift of capacitance shall be calculated for the points of measurement of Sub-clause 4.24.1.2 *a)*, *d)* and *g)* in the following manner:

$$\delta_{da} = \frac{C_0 - C_a}{C_0}$$

$$\delta_{gd} = \frac{C_g - C_0}{C_0}$$

$$\delta_{ga} = \frac{C_g - C_a}{C_0}$$

as required by the relevant specification. The largest of these values is the temperature cyclic drift of capacitance.

The capacitance drift is normally expressed in per cent.

4.25 *Storage*

4.25.1 *Storage at high temperature*

4.25.1.1 The measurements prescribed in the relevant specification shall be made.

4.25.1.2 The capacitors shall be subjected to Test Ba of IEC Publication 68-2-2 (1974), using the following severities:

Temperature: upper category temperature.
Duration: 96 ± 4 h.

4.25.1.3 After recovery for at least 16 h, the measurements prescribed in the relevant specification shall be made.

4.25.2 *Storage at low temperature*

4.25.2.1 The measurements prescribed in the relevant specification shall be made.

4.25.2.2 The capacitors shall be subjected to Test Ab of IEC Publication 68-2-1 (1974). The capacitors shall be stored at −40 °C for either a period of 4 h after thermal stability has been reached, or for 16 h, whichever is the shorter period.

4.25.2.3 After recovery for at least 16 h, the measurements prescribed in the relevant specification shall be made.

4.26 *Surge*

4.26.1 The measurements specified in the relevant specification shall be made.

4.26.2 Suitable test circuits are shown below in Fig. 8a and 8b.

Note. — The thyristor circuit has the advantage of high repetition rates and is free from troubles associated with dirty contacts and contact bounce.

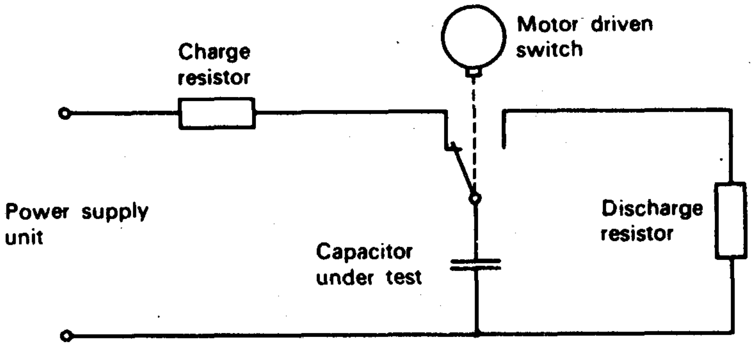


FIG. 8a. — Relay circuit

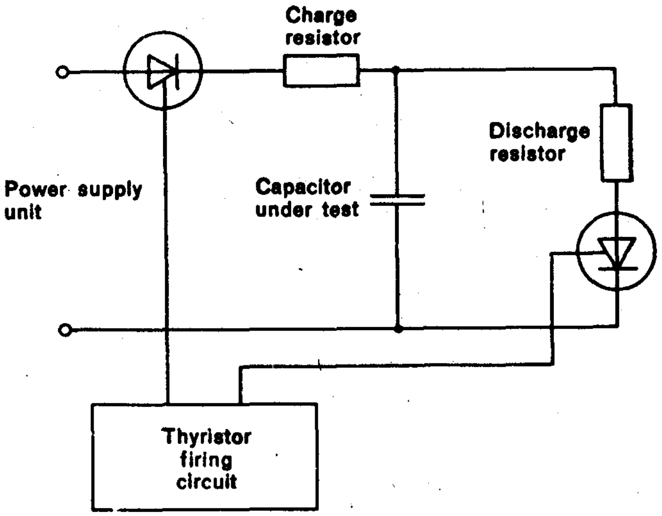
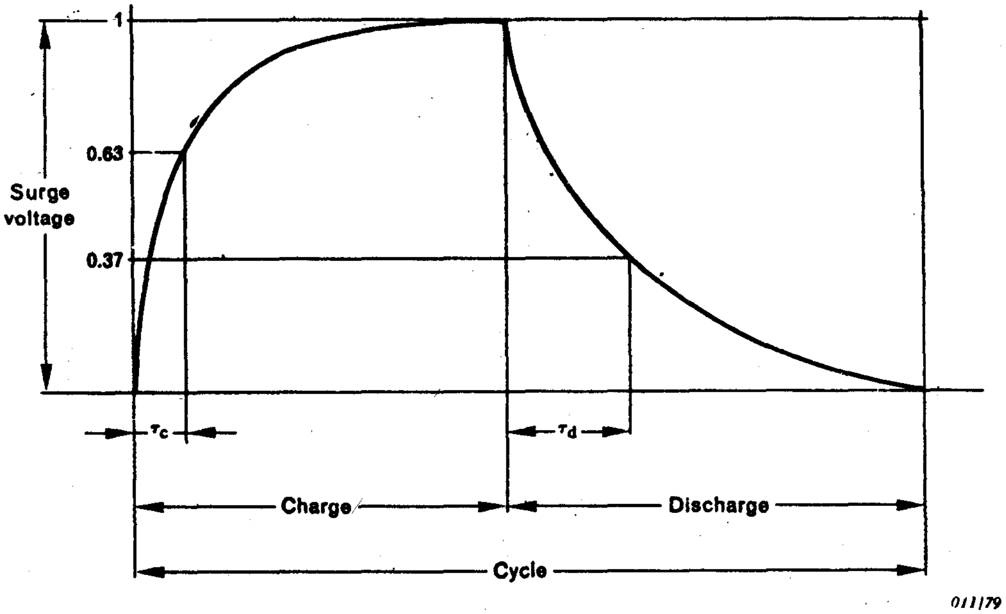


FIG. 8b. — Thyristor circuit

The voltage waveform across the capacitor under test shall be approximately as given in Fig. 9.



τ_c = charge time constant
τ_d = discharge time constant

FIGURE 9

4.26.3 The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of the power supply and the resistance of the charge circuit and the capacitor under test;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitor under test;

c) the ratio of the surge voltage to rated or category voltage (as appropriate);

d) the number of cycles of test;

e) the duration of the surge period;

f) the duration of the discharge period;

g) the repetition rate (cycles per second);

h) temperature, if different from standard atmospheric conditions for testing

4.26.4 The measurements specified in the relevant specification shall be made.

4.27 *Charge and discharge test*

4.27.1 The measurements specified in the relevant specification shall be made.

4.27.2 Suitable test circuit are given in Sub-clause 4.26.2, Figures 8a and 8b.

The voltage and current waveforms across and through the capacitor under test are approximately a follows in Fig. 10.

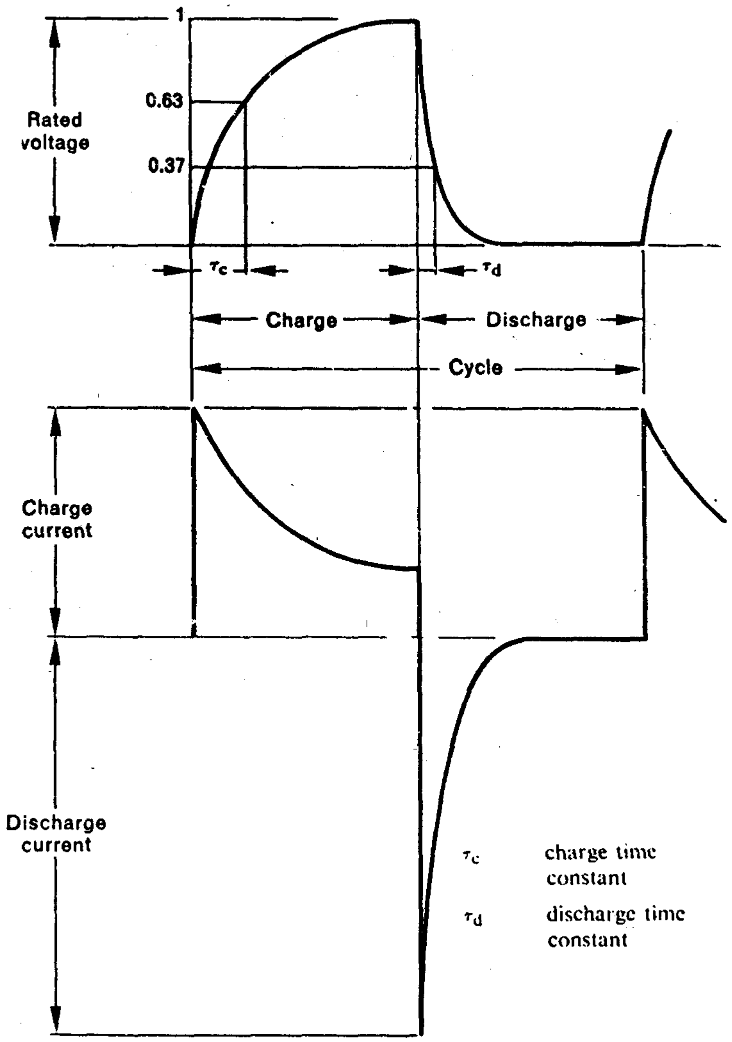


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FIGURE 10

4.27.3 The following information shall be given in the relevant specification:

a) the charge time constant arising from the internal resistance of power supply and the resistance of the charge circuit and the capacitance of the capacitor under test;

b) the discharge time constant arising from the resistance of the discharge circuit and the capacitance of the capacitor under test;

c) the voltage to be applied during the charge period, if different from the rated voltage;

d) the number of cycles of test;

e) the duration of the charge period;

f) the duration of the discharge period;

g) the repetition rate (cycles per second);

h) temperature, if different from standard atmospheric conditions for testing.

4.27.4 The measurements specified in the relevant specification shall be made.

4.28 *Pressure relief (for electrolytic capacitors)*

Unless otherwise specified in the relevant specification, one of the following tests shall be used to test the pressure relief device of the capacitors:

4.28.1 *A.C. test*

Applied voltage: alternating voltage with r.m.s. value not exceeding 0.7 times the rated direct voltage.

Frequency of the applied voltage: 50 Hz or 60 Hz.

Series resistor: $R_{\cdot}$ = 0.5 times the impedance of the capacitor at the test frequency.

4.28.2 *D.C. test*

Applied voltage: direct voltage applied in the reverse direction, of an amplitude necessary to produce a current of 1 A to 10 A.

4.28.3 *Pneumatic test*

Applied pneumatic pressure: gas pressure introduced from outside shall be increased at a rate of 20 kPa/s continuously.

4.28.4 The measurements specified in the relevant specification shall be made.

4.29 *Characteristics at high and low temperature*

The capacitors shall be subjected to the procedures of the dry heat and cold test (Sub-clauses 4.21.2 and 4.21.4 respectively) with the following details:

4.29.1 The temperatures for these tests shall be the same as for the dry heat and cold tests. Tests at intermediate temperatures may be prescribed by the relevant specification.

Measurements shall be made at each of the specified temperatures after the capacitor has reached thermal stability.

The condition of thermal stability is judged to be reached when two readings of a characteristic, taken in an interval of not less than 5 min, do not differ by an amount greater than that which can be attributed to the measuring apparatus.

4.29.2 The capacitors shall not exceed the limits as prescribed in the relevant specification.

4.30 *Thermal stability test*

A thermal stability test may constitute an alternative to the endurance test in accordance with Sub-clause 4.23.4 *d)*. The test to be carried out shall be specified in the detail specification.

The capacitor shall be loaded with a specified factor times the rated reactive power dissipation at the rated temperature and duration as specified in the relevant specification. A test for thermal stability shall be made by measuring the temperature rise as a function of time over the last part of the specified duration. The temperature rise shall be within specified limits.

The measurement of the temperature rise may be made by use of a thermocouple, thermistor, infra-red thermometer, infra-red photography etc. Care should be taken to ensure that the error of measurement does not exceed ±1° C and that errors due to heat conduction along measuring connections are kept to a minimum.

The relevant specification shall specify the point at which the measurements shall be made and the method of mounting. (See I E C Publication 68-2-2, Sub-clause 36.2).

4.31 *Component solvent resistance*

4.31.1 *Initial measurements*

The measurements prescribed in the relevant specification shall be made.

4.31.2 The components shall be subjected to Test XA of I E C 68-2-45 (1980), with the following details:

a) Solvent to be used: See Sub-clause 3.1.1 of I E C 68-2-45.

b) Solvent temperature: 23 ± 5 °C, unless otherwise specified in the detail specification.

c) Conditioning: Method 2 (without rubbing).

d) Recovery time: 48 h, unless otherwise stated in the detail specification.

4.31.3 The measurements prescribed in the relevant specification shall then be made and the specified requirements be met.

4.32 *Solvent resistance of marking*

4.32.1 The components shall be subjected to Test XA of I E C 68-2-45 (1980), with the following details:

a) Solvent to be used: See Sub-clause 3.1.1 of I E C 68-2-45.

b) Solvent temperature: 23 ± 5 °C.

c) Conditioning: Method 1 (with rubbing).

d) Rubbing material: Cotton wool.

e) Recovery time: Not applicable, unless otherwise stated in the detail specification.

4.32.2 After the test the marking shall be legible.

APPENDIX A

INTERPRETATION OF SAMPLING PLANS AND PROCEDURES AS DESCRIBED IN IEC PUBLICATION 410 FOR USE WITHIN THE IEC QUALITY ASSESSMENT SYSTEM FOR ELECTRONIC COMPONENTS

When using IEC Publication 410 (1973) for inspection by attributes, the following interpretations of the clauses and sub-clauses indicated below apply for the purpose of this standard:

1. The responsible authority is the National Authorized Institution implementing the Basic Rules and Rules of Procedure.

1.5 The unit of product is the electronic component defined in a detail specification.

2. Only the following definitions from this clause are required:

- a defect is any non-conformance of the unit of product to specified requirements;
- a defective is a unit of product which contains one or more defects.

3.1 The extent of non-conformance of a product shall be expressed in terms of per cent defective.

3.3 Not applicable.

4.5 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional specification.

5.4 The responsible authority is the Chief Inspector, acting in accordance with the procedures prescribed in the document describing the inspection department of the approved manufacturer and approved by the National Supervising Inspectorate.

6.2 The responsible authority is the Chief Inspector.

6.3 Not applicable.

6.4 The responsible authority is the Chief Inspector.

8.1 Normal inspection shall always be used at the start of inspection.

8.3.3*d)* The responsible authority is the Chief Inspector.

8.4 The responsible authority is the National Supervising Inspectorate.

9.2 The responsible authority is the IEC Technical Committee drafting the blank detail specification which forms part of the generic or sectional specification.

9.4 (Fourth sentence only.) Not applicable.
(Fifth sentence only.) The responsible authority is the Chief Inspector.

10.2 Not applicable.

APPENDIX B

RULES FOR THE PREPARATION OF DETAIL SPECIFICATIONS FOR CAPACITORS AND RESISTORS FOR ELECTRONIC EQUIPMENT

B1. The drafting of a complete detail specification by IEC Technical Committee No. 40: Capacitors and Resistors for Electronic Equipment, if required, shall begin only when all the following conditions have been met:

a) the generic specification has been approved;

b) the sectional specification, when appropriate, has been circulated for approval under the Six Months' Rule;

c) the associated blank detail specification has been circulated for approval under the Six Months' Rule;

d) there is evidence that at least three National Committees have formally approved, as their own national standard, specifications covering a component of closely similar performance.

When a National Committee formally asserts that substantial or significant use is made within its country of a part described by some other national standard, this assertion may count towards the foregoing requirement.

B2. Detail specifications prepared under the responsibility of Technical Committee No. 40 shall use the standard or preferred values, ratings and characteristics and severities for environmental tests, etc., which are given in the appropriate generic or sectional specifications.

An exception to this rule may only be granted for a specific detail specification, when agreed by Technical Committee No. 40.

B3. The detail specification should not be circulated under the Six Months' Rule until the sectional and blank detail specifications have been approved for publication.

APPENDIX C

GUIDE FOR PULSE TESTING OF CAPACITORS

C1. Introduction

Existing testing methods covered by I E C Publication 384-1 are suitable for capacitors operating in circuits where the applied voltage is predominantly direct voltage. There is now an increasing number of applications in which the applied voltage is in the form of pulse with or without a reversal of polarity. These pulses may be continuous, intermittent, or random in occurrence.

This document specifies the factors affecting pulse ratings and the way in which these ratings may be checked by appropriate endurance tests. The parameters of a pulse are defined. Different combinations of these parameters can give rise to different causes of failure as follows:

Type	*Cause of failure*	*Test*
Electrolytic	Surge voltage exceeded	Surge voltage
	Reverse voltage exceeded	Reverse voltage
	Overheating (I^2R)	Pulse or a.c.
Metallized types	Peak current	Charge/discharge (intermittent)
	$\frac{dv}{dt}$	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Ionization	a.c.
All other	$\frac{dv}{dt}$	Pulse
	Overheating (I^2R)	Pulse or a.c.
	Excess peak voltage	Surge
	Ionization	a.c.

C2. Typical capacitor pulse conditions

The figures listed below for typical applications show that test specifications requiring 100 000 or 1 million pulses correspond to operation of only 5 s to 50 s.

It will not be possible to produce one circuit which will reproduce all of the required conditions. It is likely, however, that circuits can be produced which will reproduce various groups of conditions. It does not appear possible at the present time to specify accelerated test conditions to simulate, for example, a five-year operation.

— *Examples for TV application*

S-correction

Typical peak voltages: 25 V, 50 V, 180 V
Typical peak currents: 5 A to 15 A
$\frac{dv}{dt}$ about 5 V µs

Frequencies: 15 kHz to 20 kHz
Reactive power: up to 250 var

Line tuning

Typical peak voltages: up to 1 500 V
Typical peak current: 5 A
$\frac{dv}{dt}$ 180 V/µs

Multiplier capacitors

Typical peak voltage: 10 kV d.c. with ripple
Typical peak current: 0.1 A
$\frac{dv}{dt}$ up to 1 000 V/µs

— *Examples for power electronics*

Typical peak voltages: 60 V to 100 V
Typical peak currents: 40 V to 100 A
$\frac{dv}{dt}$ 1 V/µs to 20 V/µs

Frequencies: 50 Hz to 20 kHz
Reactive power: up to 500 var

— *Examples for d.c.-d.c. converters*

Typical peak voltage: 30 V
Typical peak current: 6 A
$\frac{dv}{dt}$ 600 V/µs

Frequency: up to 20 kHz

— *Examples for switch mode power supplies*

Typical peak voltages: 15 V to 400 V
Typical peak currents: 2 A to 10 A
Frequencies: 100 Hz to 40 kHz

— *Examples for lasers and pulse light sources*

Typical peak voltages: 1 kV to 3 kV
Typical peak current: 1 000 A
$\frac{dv}{dt}$ about 500 V/µs

Frequencies: 1 kHz to 5 kHz

C3 Effect of inductance on pulse testing

Proposed pulse test methods are likely to consist of test circuits involving repetitive charge and discharge of capacitors in resistive circuits. This will result in conventional exponential current and voltage characteristics.

In many applications, however, inductive effects are of considerable importance and have a major influence on the suitability of the capacitor for the application.

These are particularly important at high values of $\frac{dv}{dt}$. If the conditions for critical damping exist $\left(R^2 = 4\frac{L}{C}\right)$ the effect is a minor modification of the shape of the charge or discharge curve which will have little effect on the severity of the test.

If, however, $R^2 < 4\frac{L}{C}$, there can be overshoot with or without damped oscillations. These can result in overstress and increased power dissipation.